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INVESTIGATIONS OF SMALL SCALE STRUCTURE OF IONISATION IN THE D REGION USING A LANGMUIR PROBE

K.H. LLOYD, G.G. O'CONNOR and C.J. BEACH

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SUMMARY

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17 **SUMMARY OR ABSTRACT:**
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Partial reflection of 2 MHz radio signals, used as a technique to measure to measure winds in the ionosphere, have shown preferential heights of enhanced reflection. A knowledge of the electron density would help in determining the reason for these preferred heights. This paper presents electron density profiles, measured on two rocket flights flown from Woomera using a nose tip Langmuir probe.

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1. INTRODUCTION

The partial reflection method of measuring ionospheric drifts involves the detection of a radio signal, reflected from the ionosphere, at spaced receivers on the ground (see, for example, references 1, 2 and 3). An analysis of the correlation between the received strengths at the different receivers gives the direction of drift of the ionospheric irregularities which produce fading in the received signal. By gating the delay time between transmission and reception of the pulsed signal, it is possible to measure the drift over a range of altitudes. It has been found that the reflected signal is much stronger at some altitudes (called "preferred heights"), separated by about 10 km. It is not clear what produces these enhanced signals.

The Physics Department of Adelaide University has for several years been operating a partial reflection experiment at Woomera in conjunction with rocket based experiments which measure the atmospheric wind profile. Measurements of the electron density using rockets, which were being conducted as part of the upper atmospheric research program, could also be used to help elucidate the nature of the preferred heights. The Langmuir probe technique was selected as being the most suitable, for it can give a continuous profile (when the probe voltage is not swept) and easily covers the range of altitudes over which the partial reflection technique was used. For the 2 MHz signal, which was the frequency used for the partial reflection equipment, the range of altitudes lay between 60 and 100 km, dependent on the time of day.

This Report presents the results of two determinations of the electron density profile in the ionosphere using the Langmuir probe technique. Small scale structure was observed which could act as scattering centres for the enhanced reflection of the 2 MHz signals.

2. LANGMUIR PROBE EXPERIMENT

The use of a Langmuir probe is a well proven method for measuring the electron density profile in the ionosphere. Although it is difficult to calibrate the probe to give absolute values of density, it is an excellent technique for measuring small scale structure in the electron density profile.

A 110 mm insulated section of the nose tip was used as the collecting probe. Its surface becomes heated to about 400°C during launch, thereby very effectively cleaning the probe. This means that there is no need for the degreasing and other procedures which are required for shielded probes. Figure 1 shows the rocket payload, both assembled and in sections.

Figure 2 shows the circuit diagram of the electronics associated with the probe. The probe current is converted to an output voltage by amplifiers, X1 and X2d. Amplifier X1 converts the current to an output voltage whilst X2d is used as a level shifter. Two telemetry outputs are sampled, a times one amplification from X2d and a times three amplification from X2c. In addition, there is a 3 decade autoranging switching circuit, which connects the 470 kΩ, 4.7 MΩ and 47 MΩ feedback resistors sequentially across the amplifier X1, when the output voltage from X2d reaches two predetermined levels. The telemetry output at TH7 indicates the range of current the instrument is measuring.

A calibration curve of current vs. voltage for the probe is shown in figure 3. It has been plotted on a logarithmic scale to show all three ranges. In fact, over any range, the variation of voltage with current is linear to very near voltage saturation. The autoranging circuit was provided with hysteresis, shown by the arrowed loops, to minimise switching due to small current fluctuations.

The Langmuir probe was held at +2.7 V with respect to the rocket body. The voltage was deliberately not swept, because the prime data requirement was a continuous profile of the electron density and not electron temperature.

The data were telemetered to ground using a standard 450 MHz transmitter, with a 24 channel switch which sampled the outputs of the experiments in turn. These rockets also carried a swept frequency ionospheric plasma probe. There is no evidence of modulation of the Langmuir probe current at the sweep rate of the plasma probe; i.e. the plasma probe had no effect on the operation of the Langmuir probe.

3. LANGMUIR PROBE DATA

Two Langmuir probe experiments were flown; the first on Cockatoo 4020, fired 27 May 1976 at 1230 hours C.S.T., and the second on Lorikeet 2012, fired 30 June 1976 at 1106 hours C.S.T. Both experiments were successful, recording complete data on both up and downlegs.

A section of data, chosen to show the operation of the autoranger over a region in which the electron density varied rapidly with altitude, is shown for both flights in figures 4 and 5. As can be seen in figure 5, there was a small amount of modulation on the telemetry record for the Lorikeet experiment. The modulation frequency at the higher current levels was the same as the rocket spin rate. The modulation appears to be associated with changes in body potential caused by variation in photoelectric emission as the spinning rocket shows different surfaces to the sun. At the lower current levels this spin modulation is no longer evident due to the slower response time of the amplifier. However, there is a small amount of noise caused by interference from the other telemetry channels.

The telemetry record contains the X1 and X3 voltage output from the Langmuir probe, the range indicator of the autoranger, and +0 and +5 V references.

Final profiles for the probe current as a function of altitude are given in figures 6 and 7. No attempt has been made to convert these to absolute electron profiles. This is not necessary for our requirements; besides which, such a conversion is notoriously inaccurate.

The agreement between the upleg and downleg is generally good, especially in regard to the small scale features of the profile. This confirms that the effects of vehicle attitude are not important. The only noticeable attitude effect on the records is that of "inversion" of the vehicle upon re-entry on the downleg. This produced a dip in current at 71 km and 73 km on the two firings (that this coincided with "inversion" was confirmed from telemetry signal strength records). Below about 80 km the upleg currents are increasingly greater than those on the downleg. This is attributed to effects of outgassing from the spent second stage. However, as can be seen, this does not permanently affect the probe. The reason why outgassing lasted to a greater height for the Cockatoo 4020 than it did for Lorikeet 2012 is almost certainly because the propellants for the two motors were very different.

4. DISCUSSION OF RESULTS

For our purposes, the points of interest in the profile are the presence of layers, ledges or discontinuities in the electron density profile. It is these which are thought to give rise to the "preferred heights" of enhanced reflection.

The gross features of the profiles have the characteristics typical of the D and lower E region. That is, an exponential increase of electron density with altitude from the lowest altitudes up to approximately 95 km, broken by a valley which extends from 75 to 85 km. Associated with the valley is the ledge in electron density, again a common feature at around 80 km altitude, which lies at 84 km for Cockatoo 4020 and 83 km for Lorikeet 2012. However, the valley below the ledge is much more pronounced in the Cockatoo profile than in that of the Lorikeet.

The gross features of the two measured profiles are very similar and so too are many of the small scale features. Both profiles have a pair of discontinuities at about 92 km, although this is much more pronounced for the Cockatoo profile. Also, both profiles show structure above the 84 km ledge, differing on the up and downleg; this time the structure being more pronounced for the Lorikeet profile. This structure is almost certainly genuine, and is an indication of the scale and variability of the electron density in the atmosphere.

5. ACKNOWLEDGEMENTS

The rockets were fired as part of the Upper Atmosphere Research project, by Field Experiments Group under the direction of R. Bissell.

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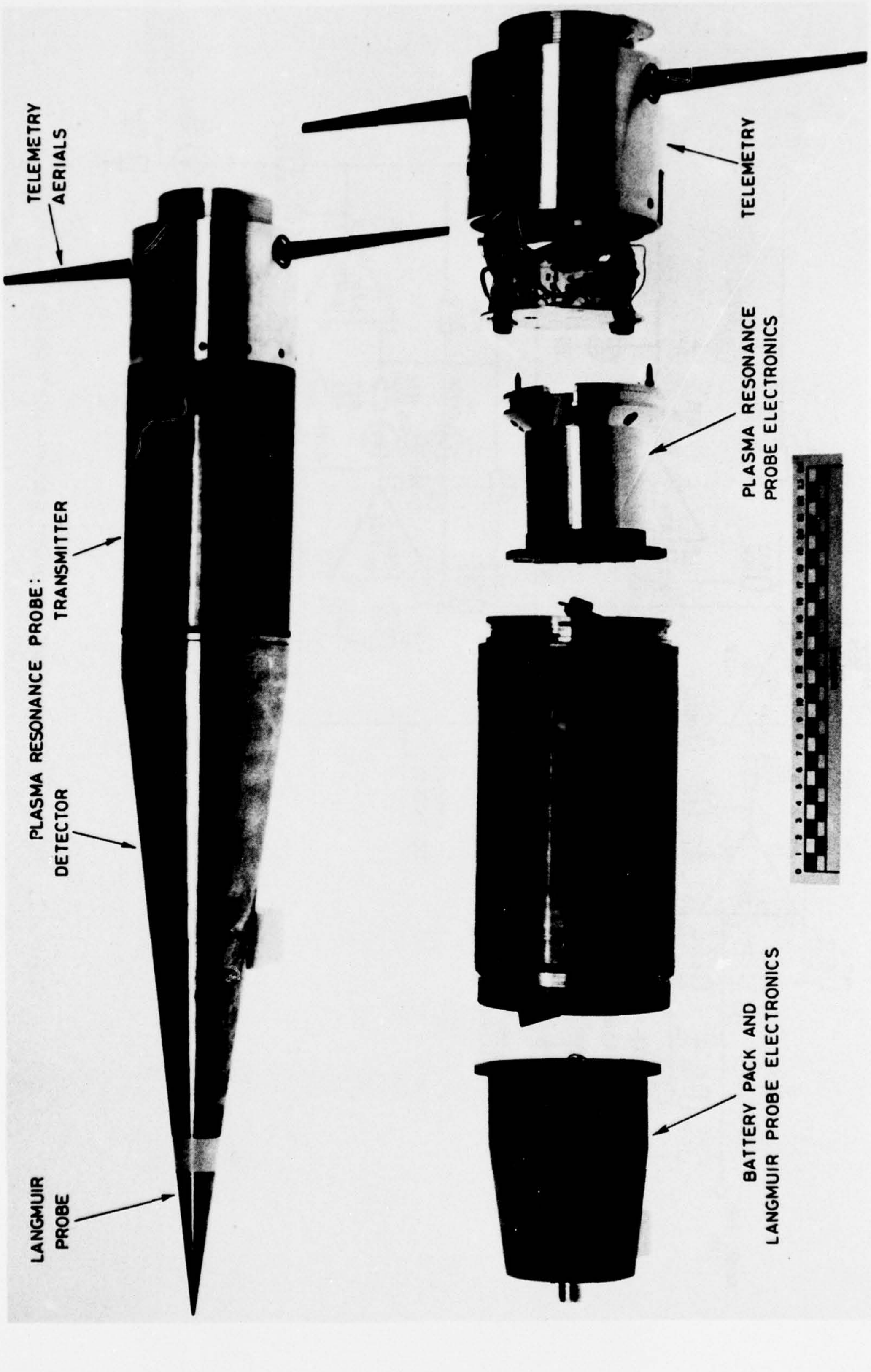

Figure 1. Payload of Cockatoo 4020

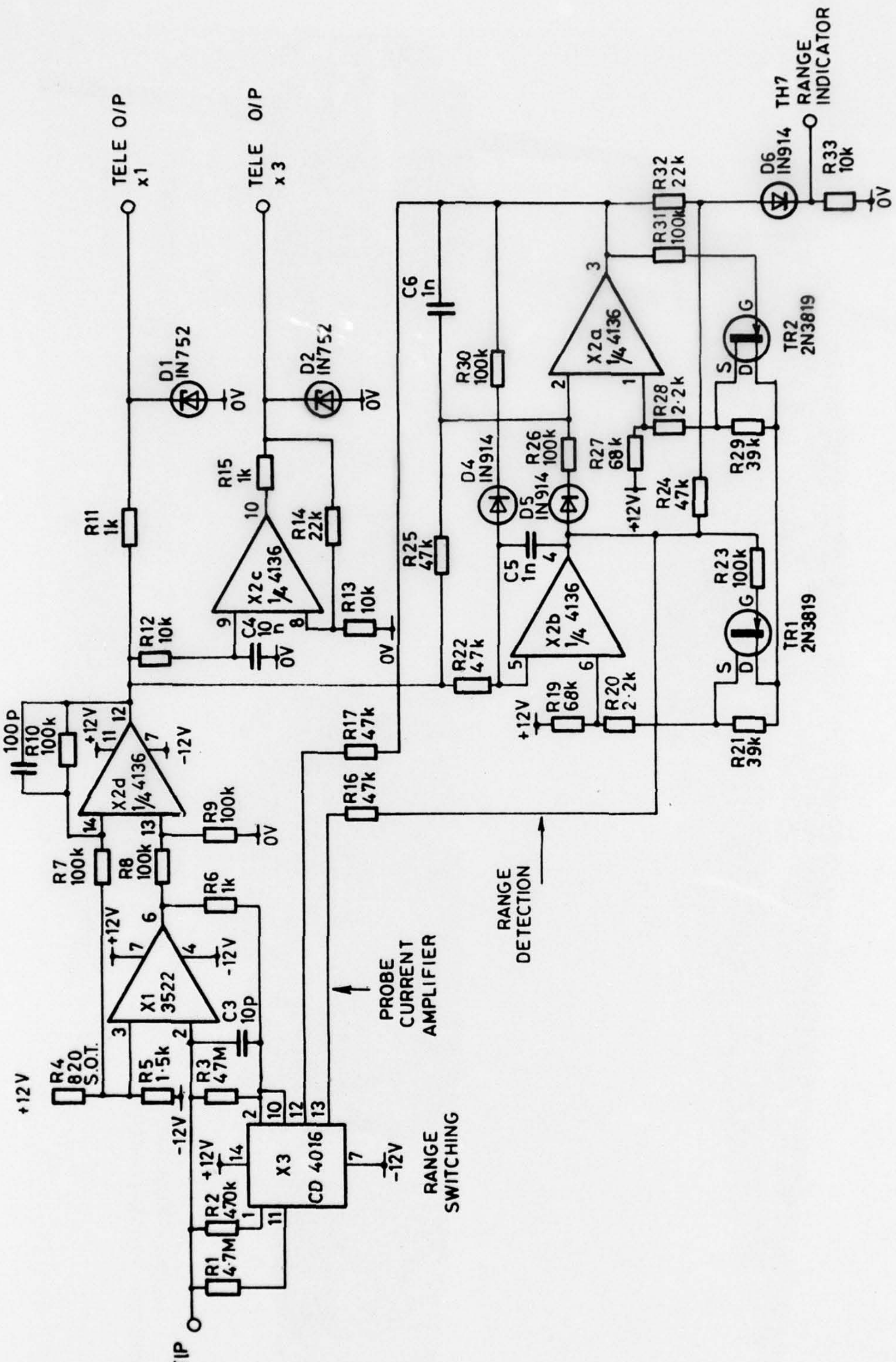

Figure 2. Circuit diagram of Langmuir probe electronics

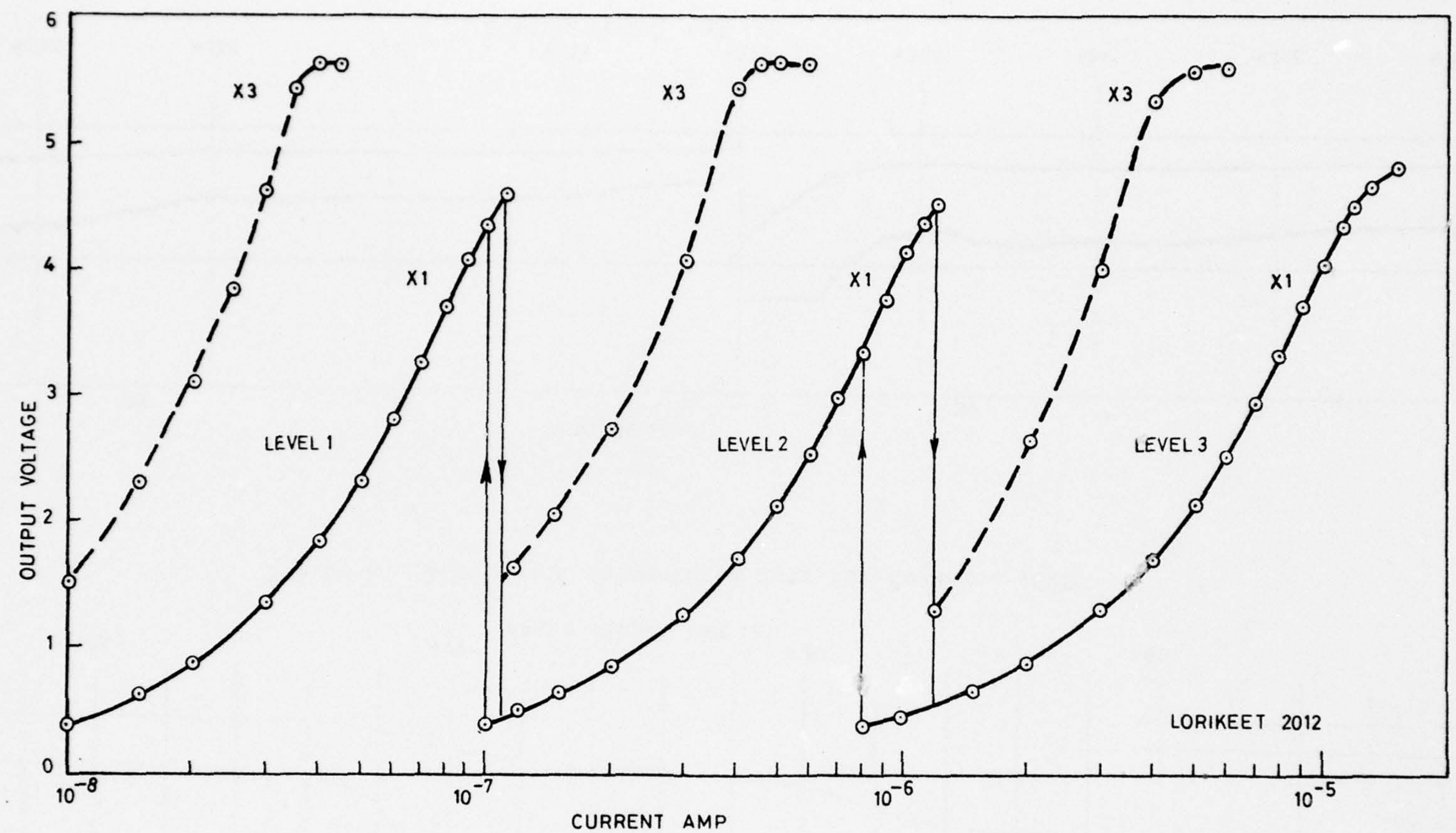

Figure 3. Current vs. output voltage calibration curve

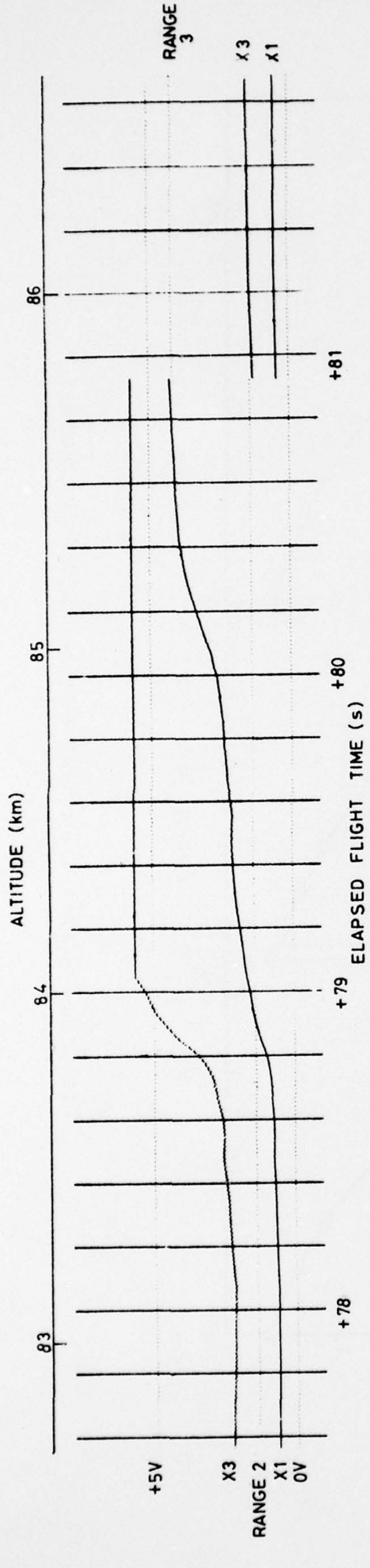

Figure 4. Section of telemetered data for Cockatoo 4020

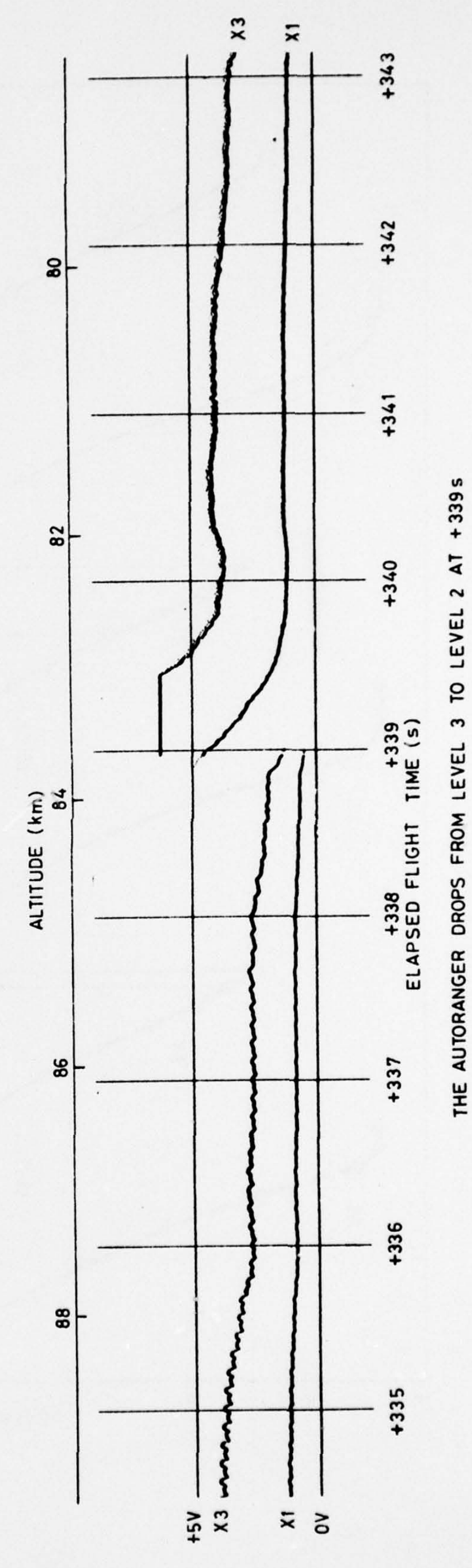

Figure 5. Section of telemetered data for Lorikeet 2012

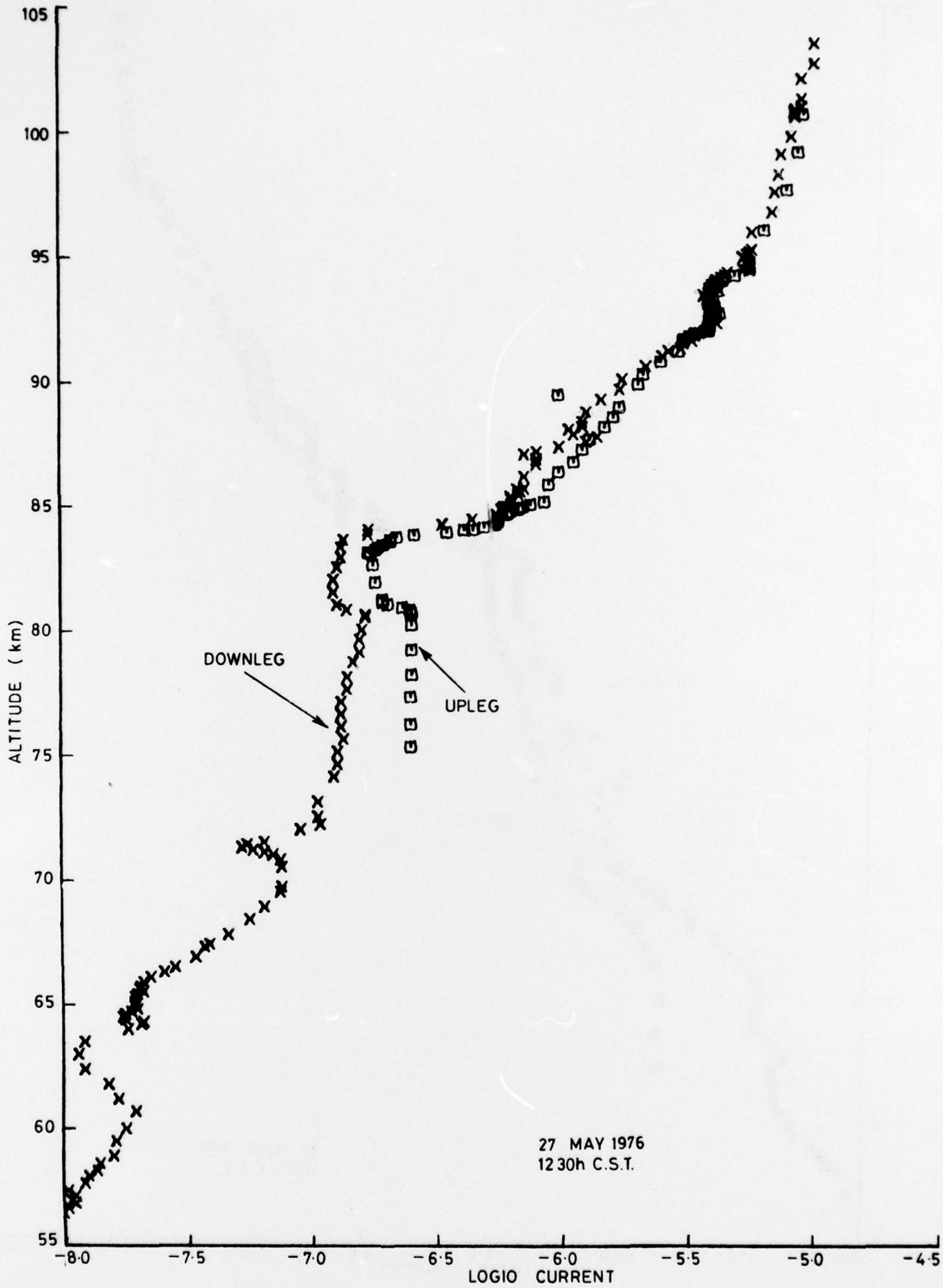

Figure 6. Langmuir probe current for Cockatoo 4020

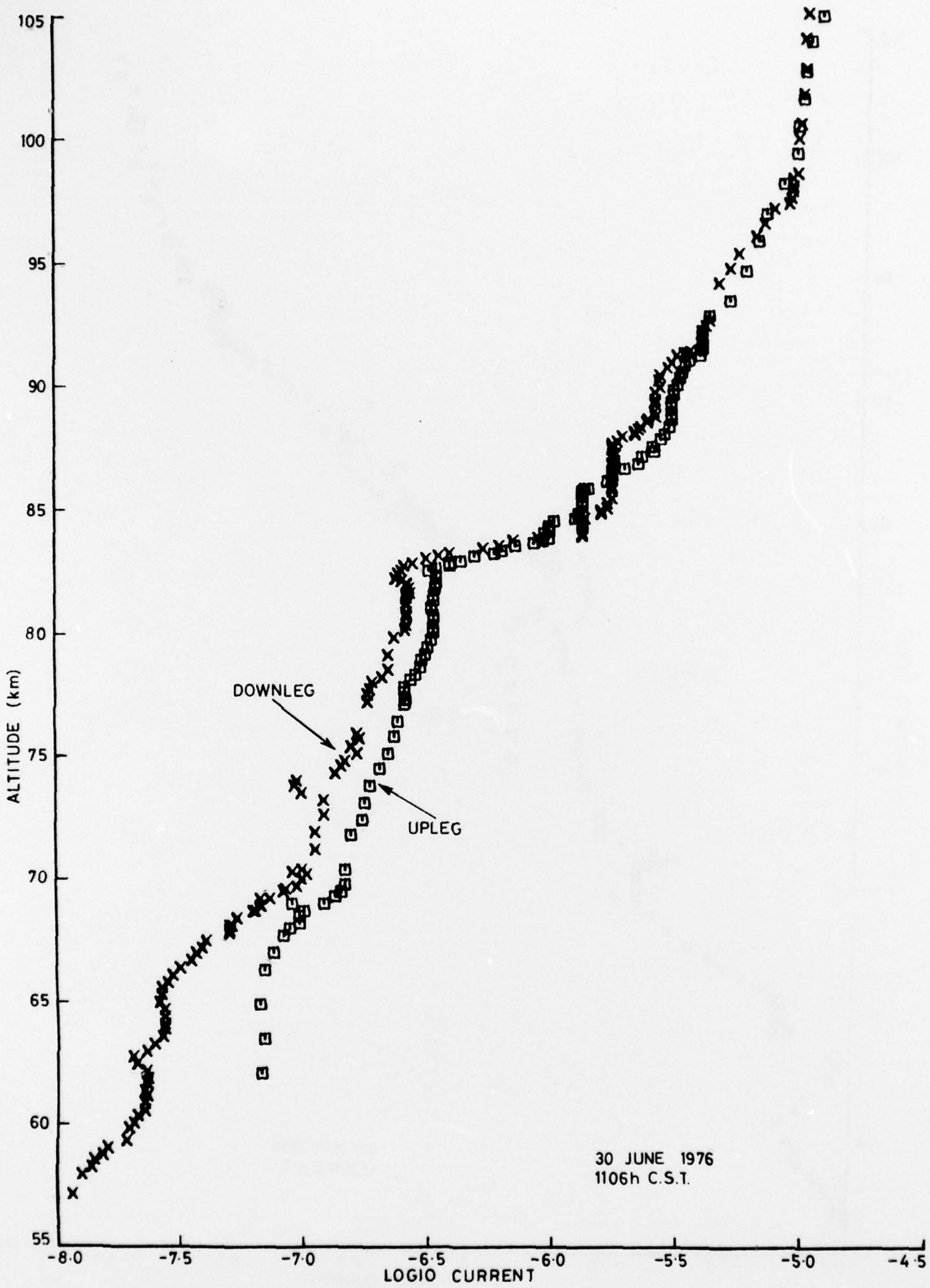

Figure 7. Langmuir probe current for Lorikeet 2012

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